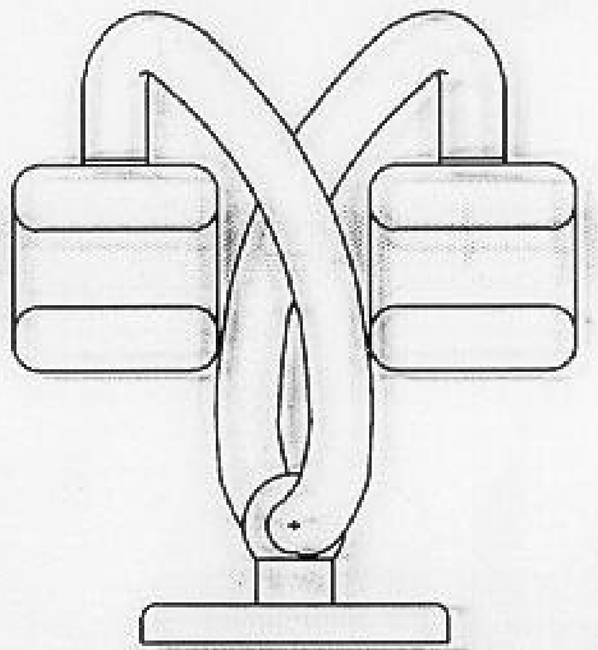
The Rare Isotope Accelerator Facility

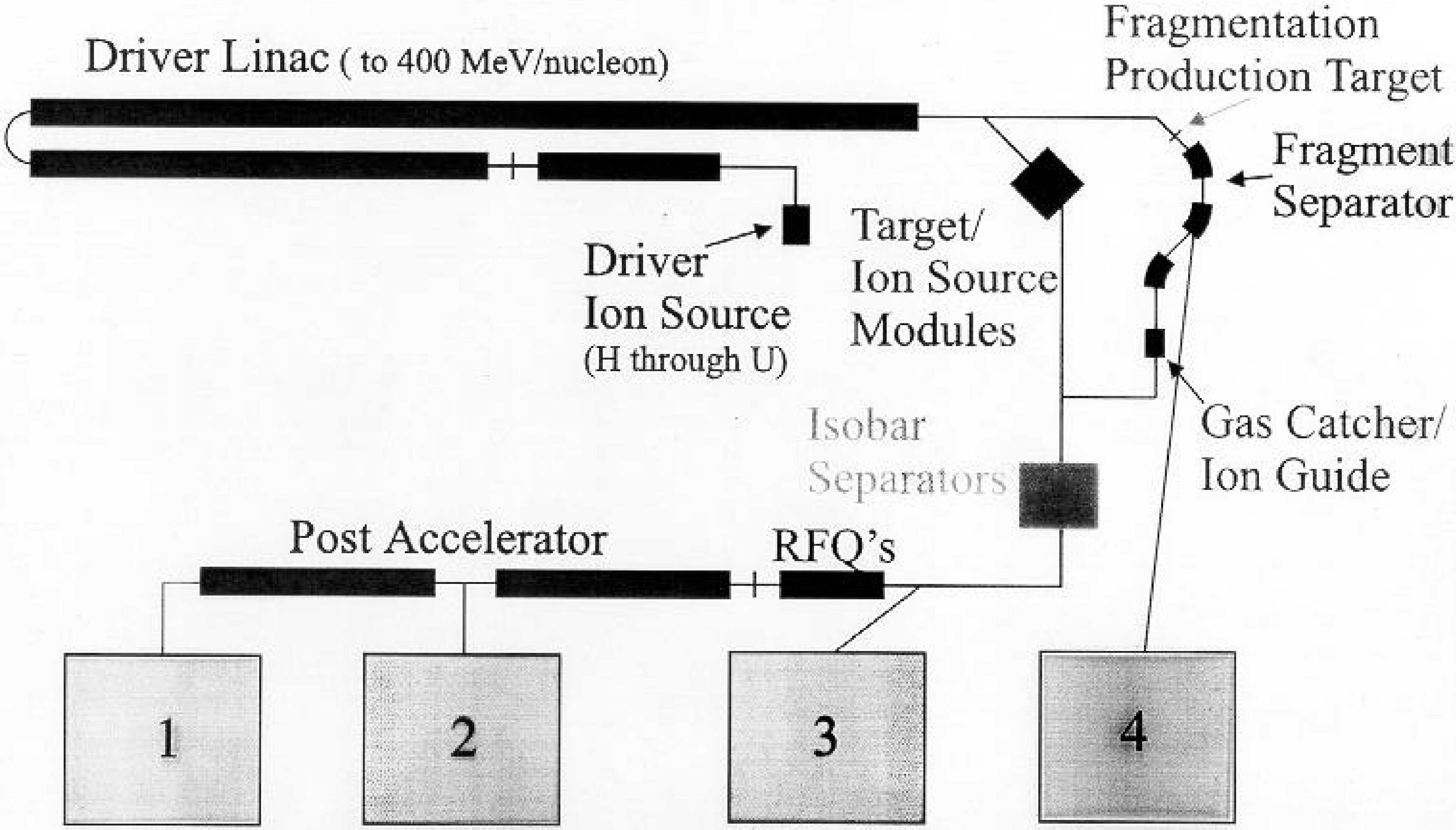
Overview of the Project



Presentation for the
RIA Applications Workshop
Los Alamos, October 30, 2000

Jerry Nolen
Physics Division
Argonne National Laboratory

Simplified Schematic Layout of the Rare Isotope Accelerator (RIA) Facility



Experimental Areas:

1: < 12 MeV/u   2: < 1.5 MeV/u   3: Nonaccelerated   4: In-flight fragments

The RIA Project in a Nutshell

RIA is a proposed facility for nuclear science with beams of rare isotopes.

RIA will produce intense beams of rare isotopes at energies from 0-400 MeV per nucleon.

The projected cost to construct RIA is ~$600M. (Including the added in-flight high energy beam capability.)

If NSAC endorses the RIA concept in FY2001, construction could start in FY2004.

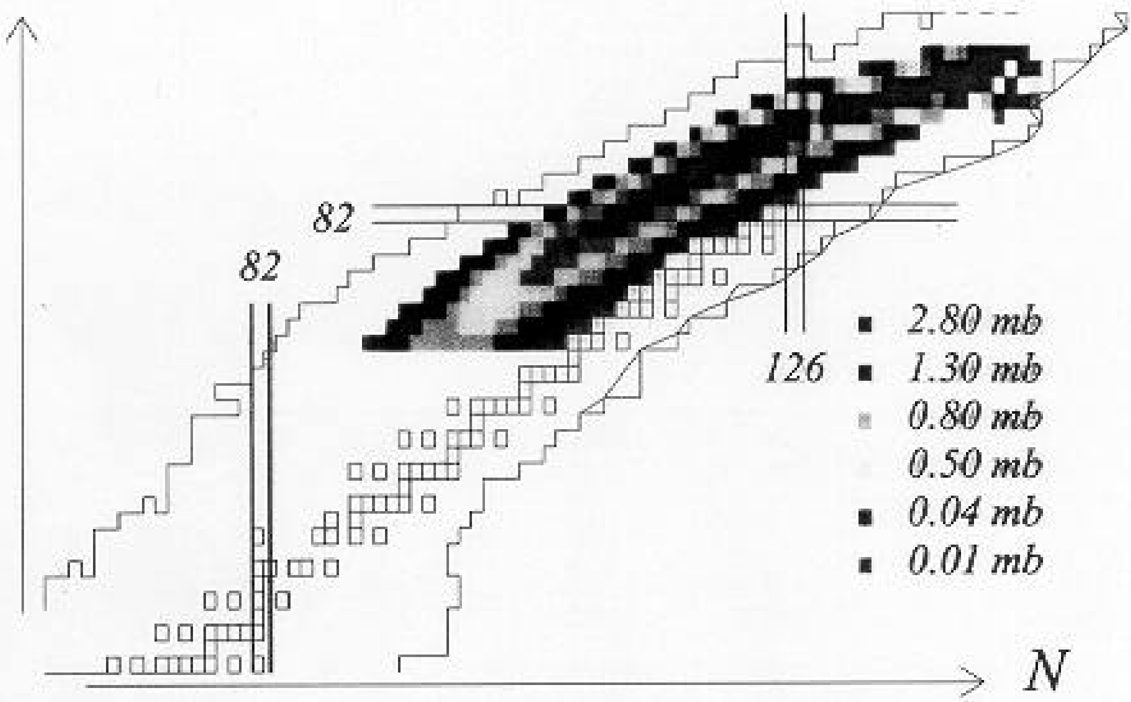
There are two proposed sites for RIA: ANL and MSU.
Site selection could occur in early FY2002.

Science with RIA could begin in FY2008.

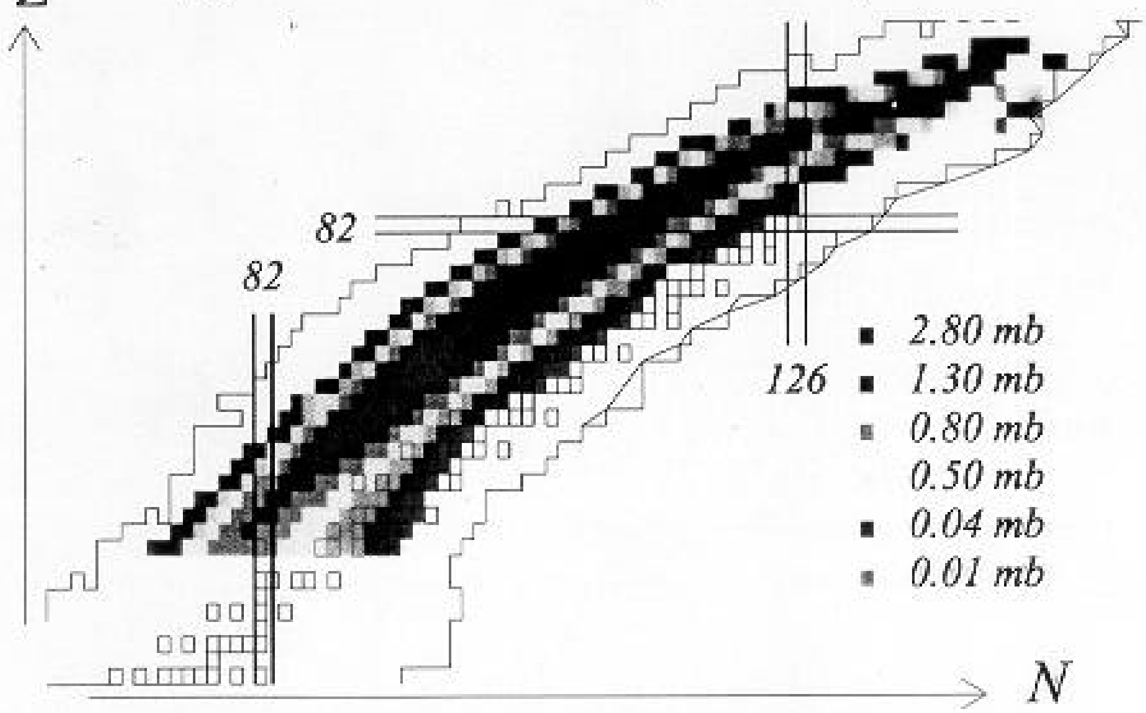
Features of RIA that may be useful in a variety of applications

- **Unprecedented yields of separated beams of radioisotopes**
  - Fast extraction, ~milliseconds
  - Chemical independence
  - High specific activity
  - Any energy, 0-400 MeV/u
- **CW beams of custom-moderated neutrons**
  - Fast, thermal, ultracold
- **Intense high-energy neutron beams**
  - Inverse kinematics: U + Li
  - Neutron energy 100-400 MeV
- **Complete set of nuclear technologies and instrumentation**
  - E.g. high sensitivity mass analysis (AMS) in the post accelerator
- **???**
  - E.g. muons for μSR

(a) 238U+proton (1A GeV)



(b) 238U+deuteron (1A GeV)



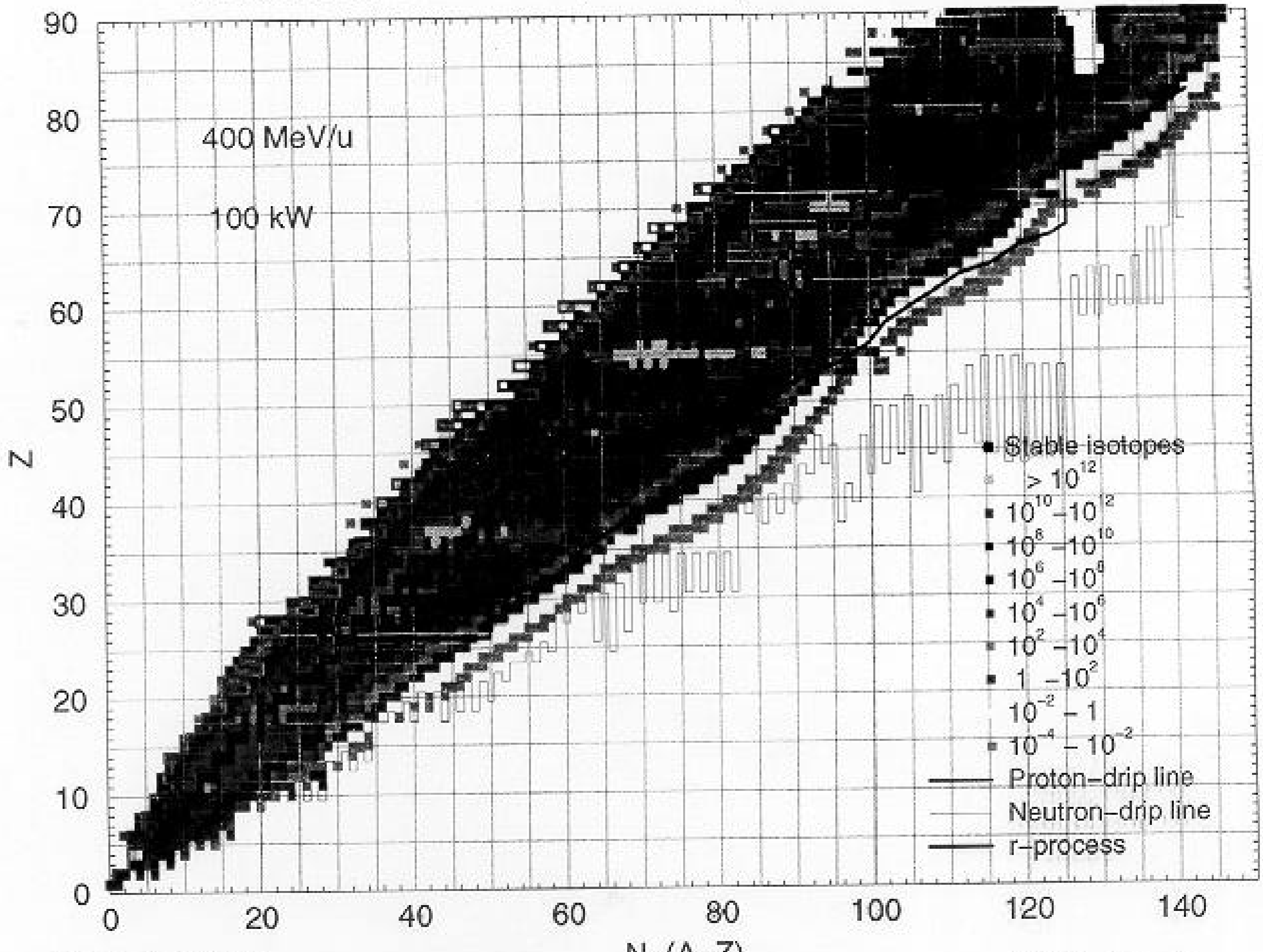
E. Casarejos, et al., RNB-5, April, 2000
S184 Collaboration.

Developments for RIA

- Post-Accelerator Based on ATLAS
  - World's first superconducting ion accelerator
- Multi-Beam Driver
  - 400 kW Superconducting Linac (protons to uranium)
  - Accelerates 5 charge states after stripping
- Liquid Lithium Targets
  - for 100 kW heavy ion beams (from fusion R&D)
- Two-step Target Concept
  - neutron generator (d+W > n+U)
- Fast Gas Catcher
  - short release times,
  - chemical independence,
  - no ion source
- CW 1+ RFQ
  - high-quality, efficient post accelerator
- $1+ \rightarrow 2+$ stripping
  - efficient stripping at very low velocity in helium gas

Yields for an Advanced ISOL Facility

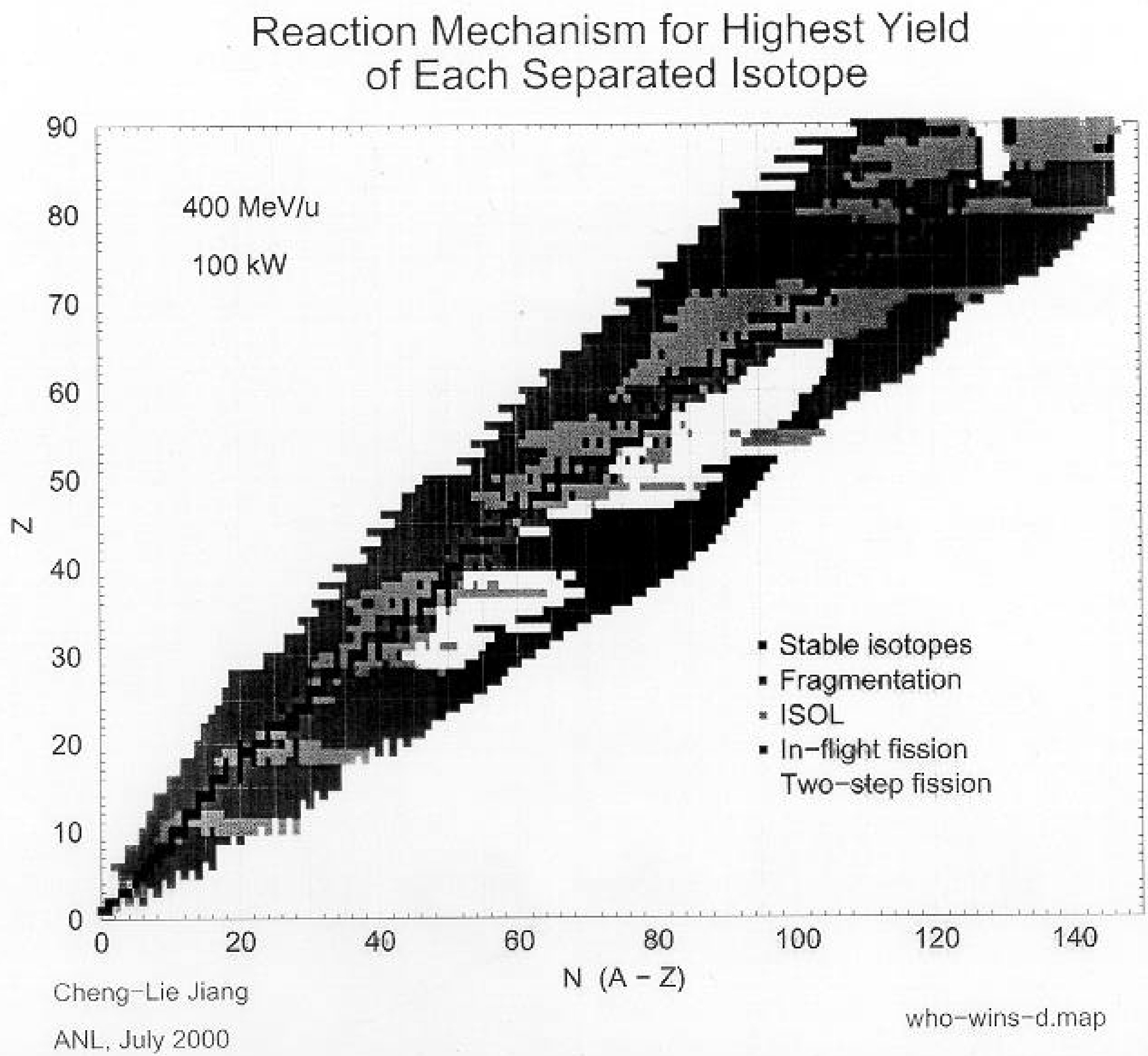
From a Multibeam Driver, Mass Separated Intensities (ions/s)



Cheng–Lie Jiang

ANL, July 2000

Yield–400–d.map


Reaction Mechanism for Highest Yield
of Each Separated Isotope
400 MeV/u
100 kW
Z
N (A − Z)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
Stable isotopes
Fragmentation
ISOL
In−flight fission
Two−step fission
Cheng−Lie Jiang
ANL, July 2000
who−wins−d.map

SC DRIVER LINAC FOR A RARE ISOTOPE FACILITY

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Abstract

An ion linac formed of superconducting rf cavities can provide a multi-beam driver accelerator for the production of nuclei far from stability. A multi-beam driver supports a wide variety of production reactions and methods. This paper outlines a concept for a 1.3 GV linac capable of delivering several hundred kilowatts of uranium beam at an energy of 400 MeV per nucleon. The linac would accelerate the full mass range of ions, and provide higher velocities for the lighter ions, for example 730 MeV for protons. The accelerator will consist of an ECR ion source injecting a normally conducting RFQ and four short IH structures, then feeding an array of more than 400 superconducting cavities of six different types, which range in frequency from 58 to 700 MHz. A novel feature of the linac is the acceleration of beams containing more than one charge state through portions of the linac, in order to maximize beam current for the heavier ions. Such operation is made feasible by the large transverse and longitudinal acceptance provided by the large aperture and high gradient which are characteristic of superconducting rf cavities.

1 INTRODUCTION

For more than a decade there has been discussion and study in the North American nuclear physics community concerning the possibility of an advanced facility for generating intense beams of isotopes far from stability [1]. Several years ago, a design concept for such a facility, based on a multi-beam ion accelerator driver was put forward [2,3]. In late 1998, the Nuclear Science Advisory Committee (NuSAC) for the U.S. Department of Energy and the National Science Foundation recommended that construction of a rare-isotope accelerator (RIA) facility be given high priority [4]. More recently, a subcommittee of NuSAC has reviewed technical options for such a facility and recommended that the driver accelerator for such a facility be capable of providing beams of all ions from protons to uranium at energies of at least 400 MeV/nucleon. A further specification is that the driver should be capable of providing 100 kW of beam power initially, and be upgradeable to 400 kW for all ions [5]. This paper outlines a design for a heavy-ion linac capable of meeting these specifications.

2 OVERVIEW OF THE LINAC

Fig. 1 shows a block diagram of the proposed linac, with uranium as the benchmark beam. Parameters of the various sections are detailed in Table 1. For the first 10 MV of the linac normal-conducting accelerating structures can be used, since they can provide adequate performance and are somewhat more cost-effective at the lowest velocities. For the remaining 99% of the linac, however, superconducting (SC) structures have numerous advantages in addition to enabling cost-effective cw operation [6].

The independent phasing intrinsic to a SC cavity array allows the velocity profile to be varied, and enables higher energies for the lighter ions. The present design for a 400 MeV/nucleon uranium linac can also provide 730 MeV protons.

To obtain broad velocity acceptance, the accelerating cavities are necessarily short, allowing the linac to be configured with ample transverse focussing. Also, since SC structures provide high accelerating gradients, strong longitudinal focussing can be obtained by

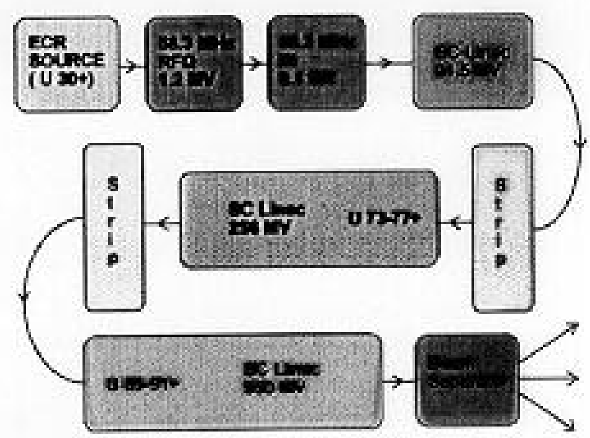
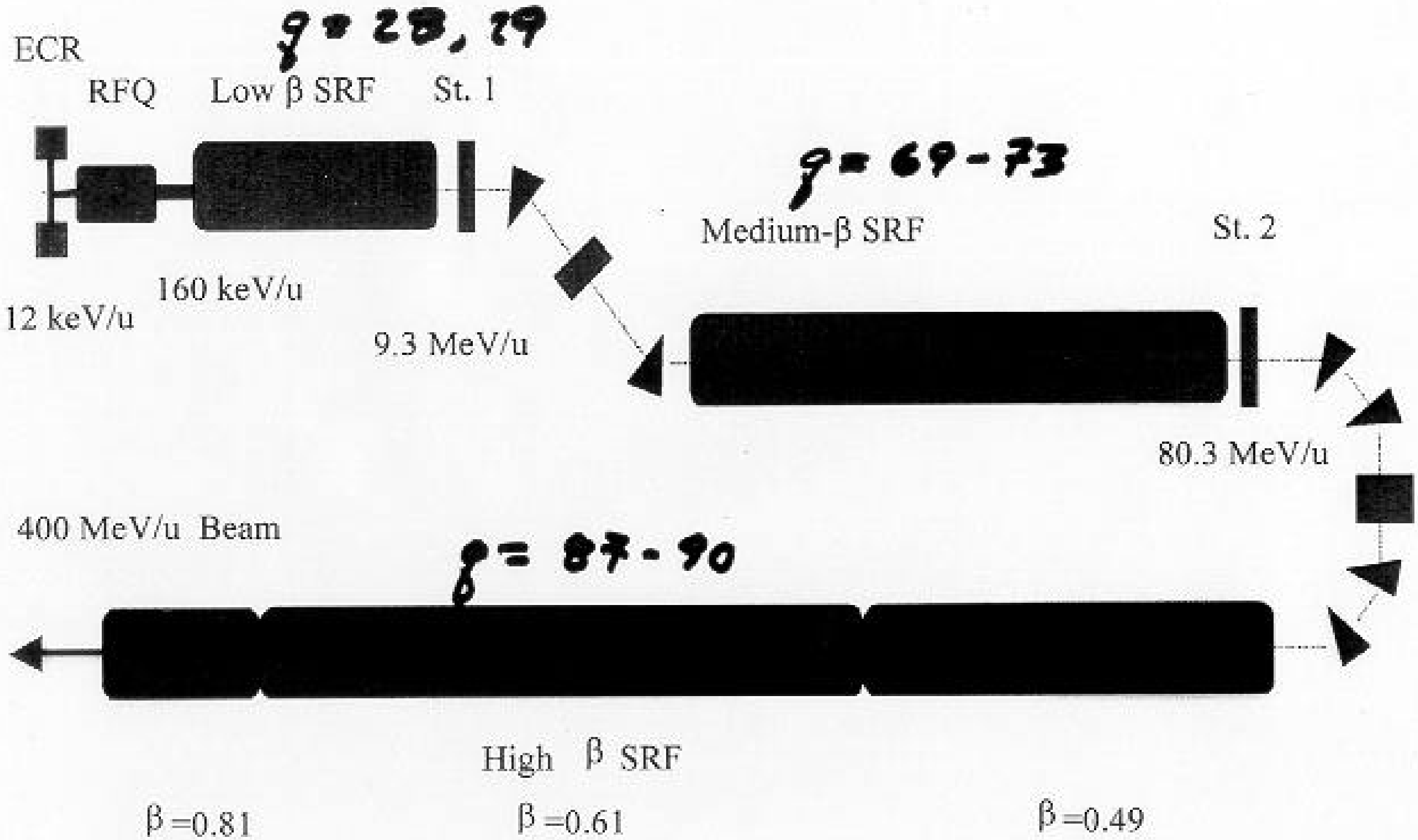


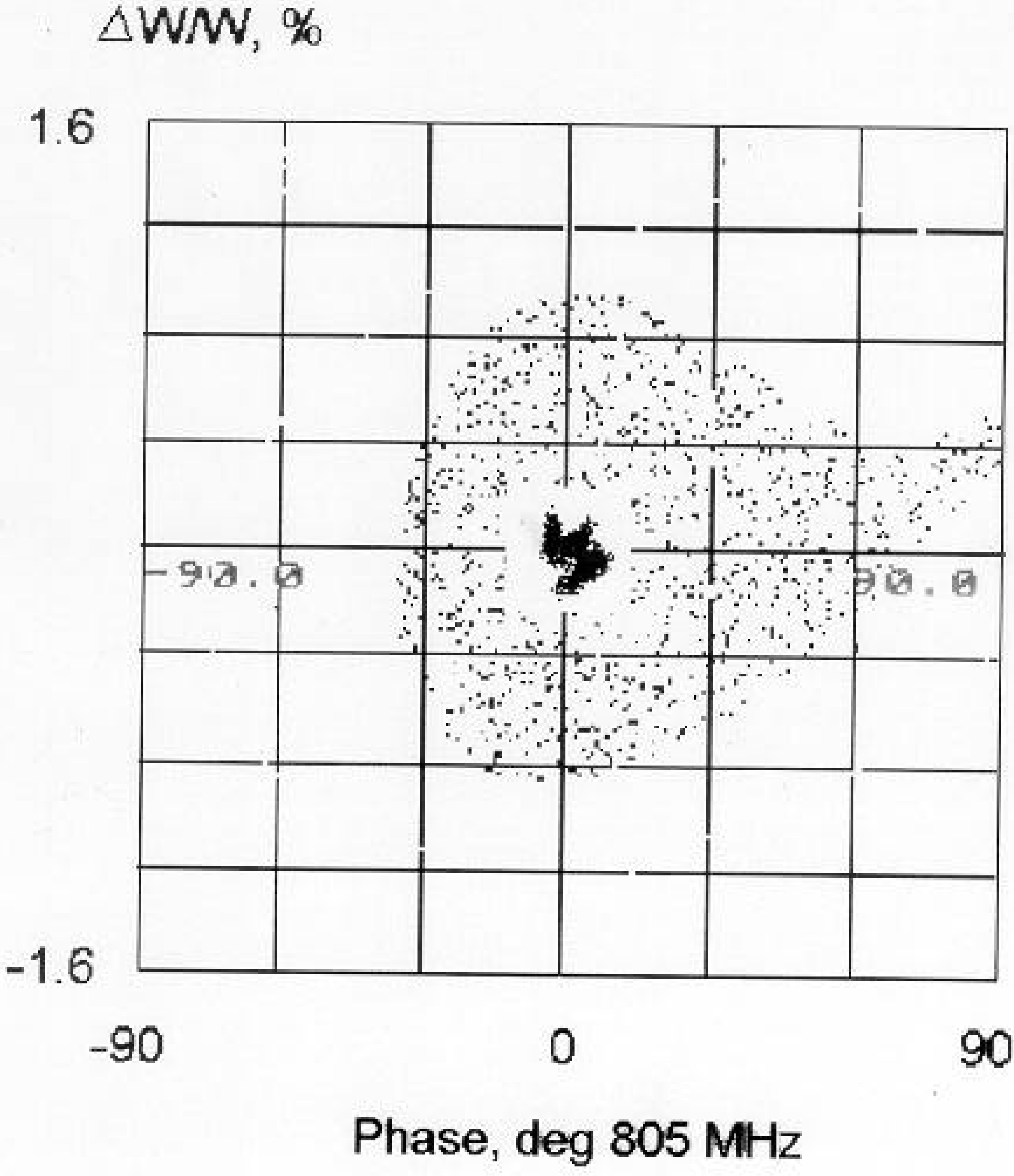
Figure 1: Elements of the proposed linac

[1] Argonne National Laboratory
[2] Jefferson National Accelerator Facility
[3] Lawrence Berkeley National Laboratory



g = 28, 29
ECR
RFQ
Low β SRF
St. 1
g = 69 - 73
Medium-β SRF
St. 2
160 keV/u
12 keV/u
9.3 MeV/u
80.3 MeV/u
400 MeV/u Beam
g = 87 - 90
High β SRF
β =0.81
β =0.61
β =0.49

Five Charge State Uranium Beam at the Location of the Second Stripper (80 MeV/u)

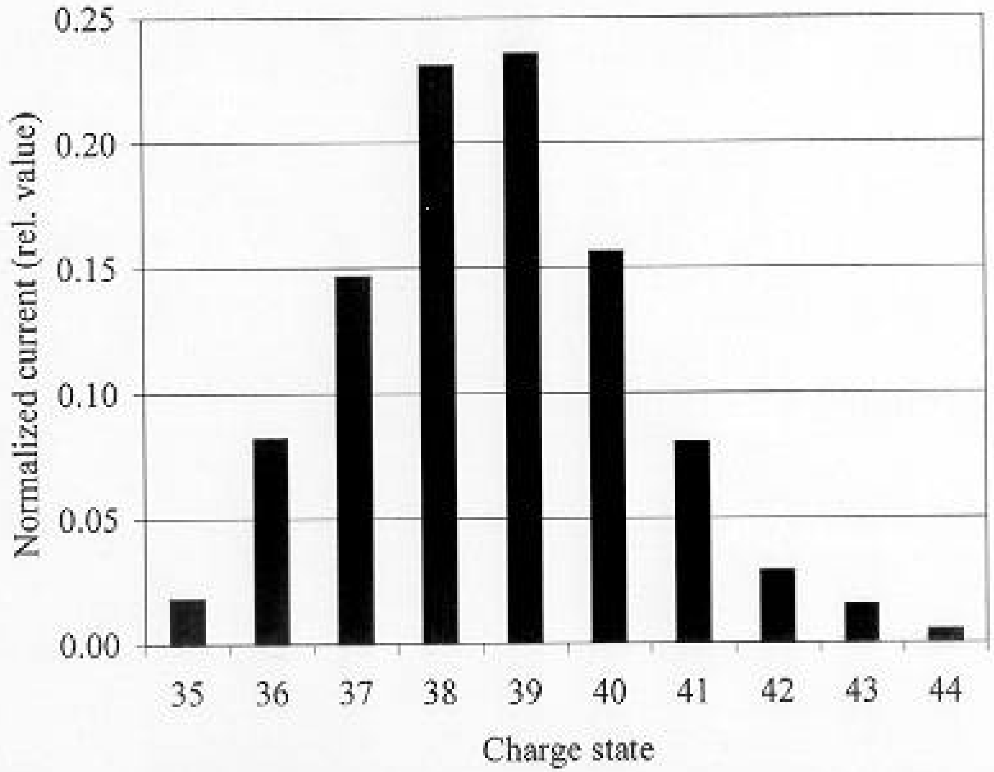


P.N. Ostroumov & K.W. Sheppard, PRSTAB, Feb 2000.

Multi-Q Beam Test at ATLAS
ANL, July 11-15, 2000

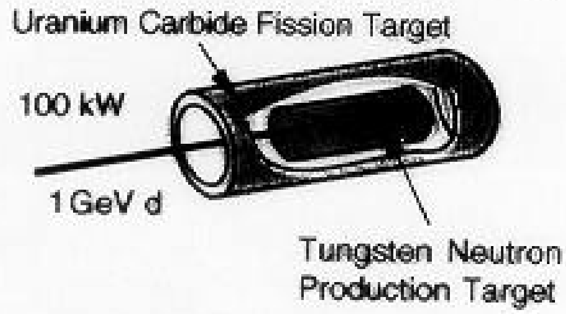
Transmission of multi-Q accelerated beam through the booster

10 mm input aperture: 94%



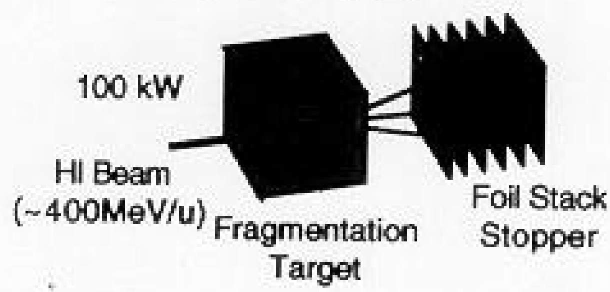
Argonne Concepts for ISOL Production Targets

2-Step Fast Neutron Fission



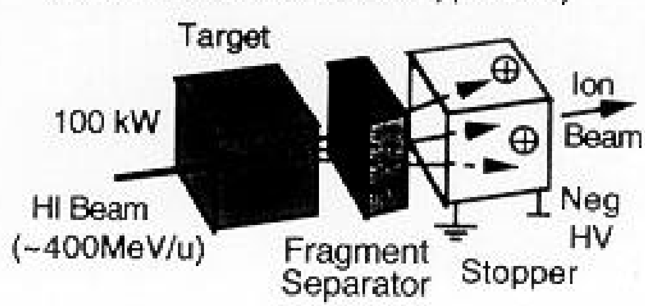
2-Step Projectile Fragmentation

(Solid Stopper)

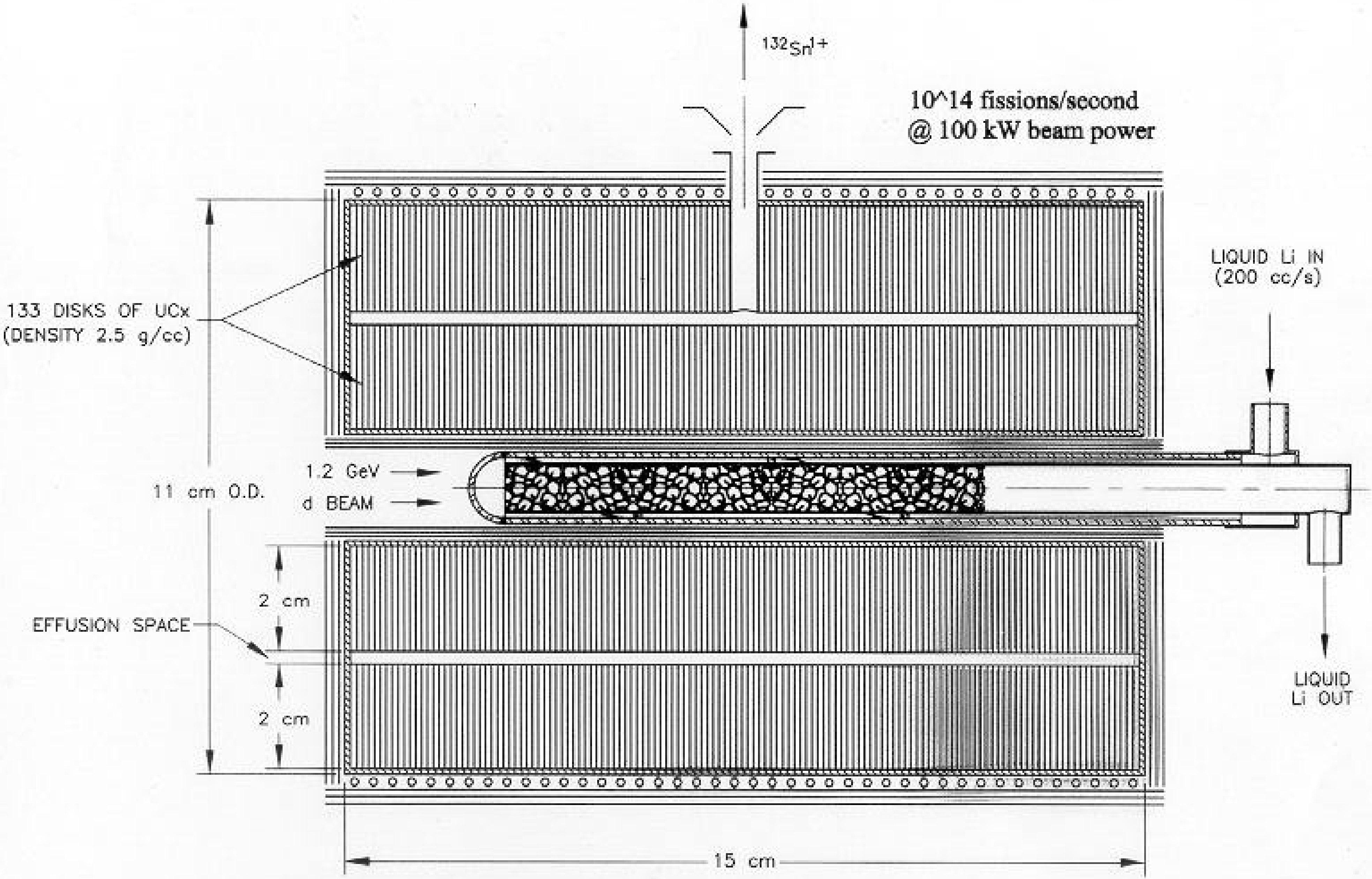


2-Step Projectile Fragmentation

(High Pressure He Gas Stopper Cell)

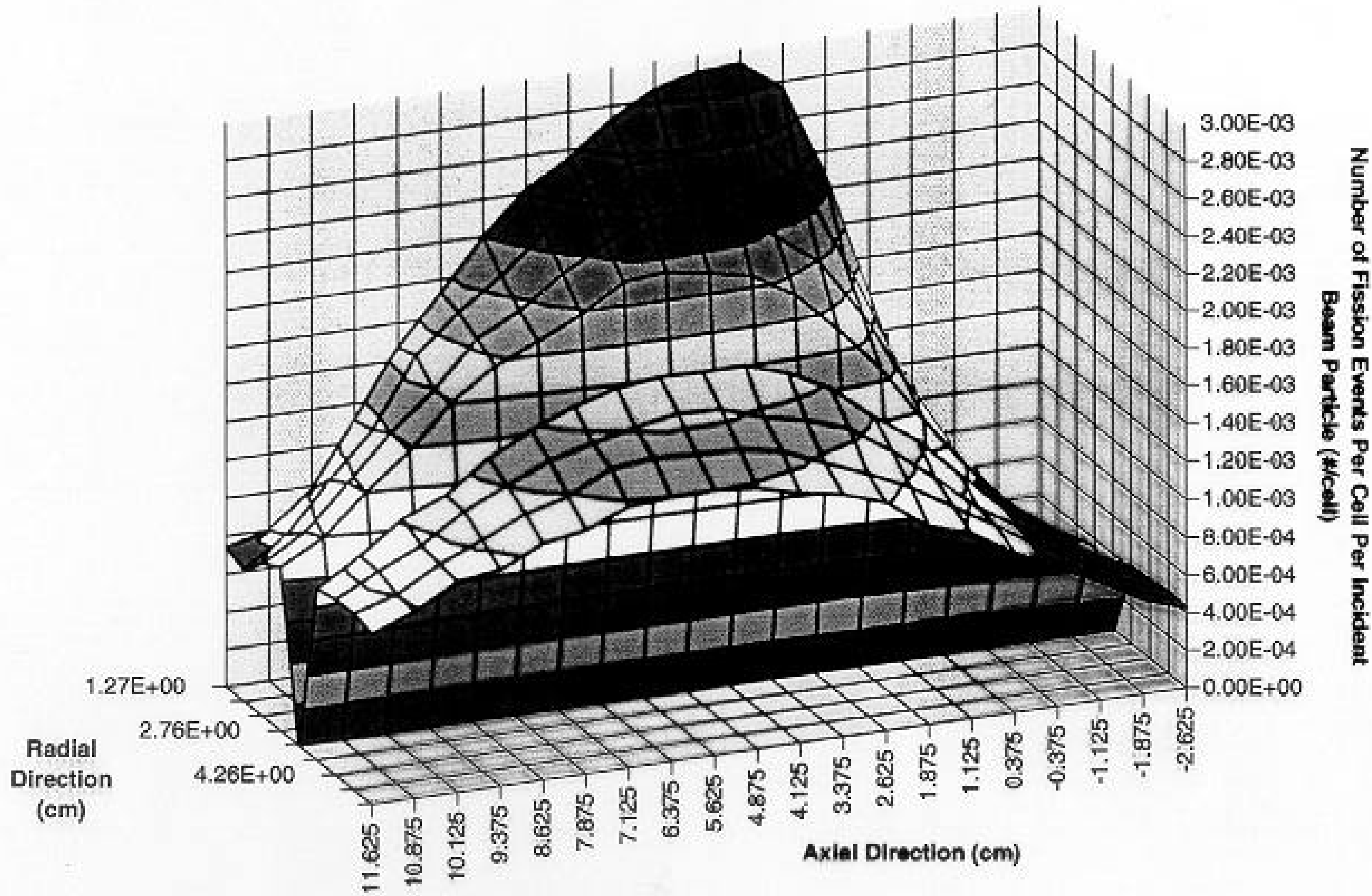


One-Step Spallation Target



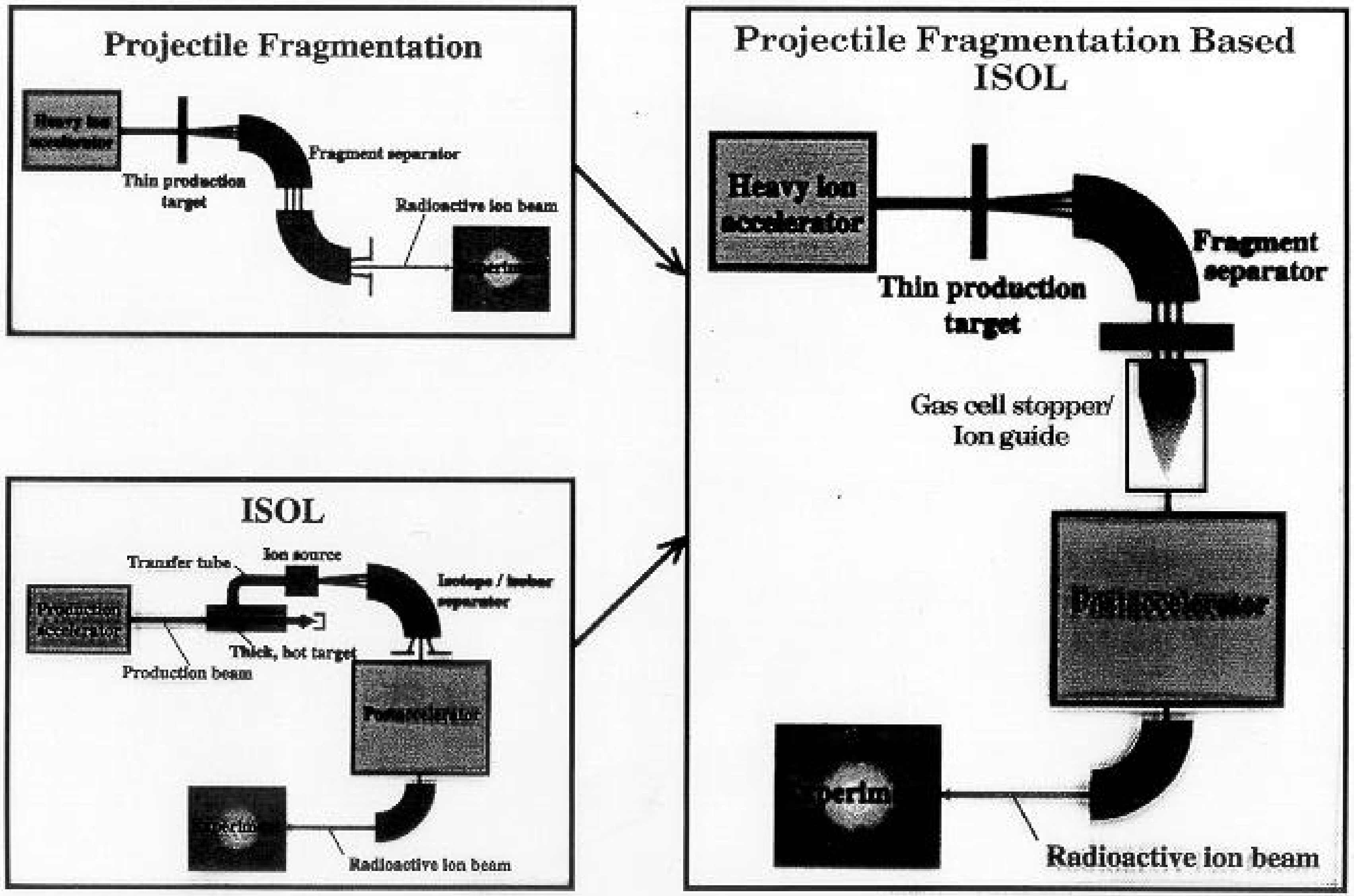
LIQUID-LITHIUM COOLED TUNGSTEN TARGET/ION SOURCE

Total Number of Fission Events Per 0.5cm Radial Increment in the Secondary Target (Lahet + Below 20MeV) - W.D.1.2GeV - Values are per Incident Beam Particle

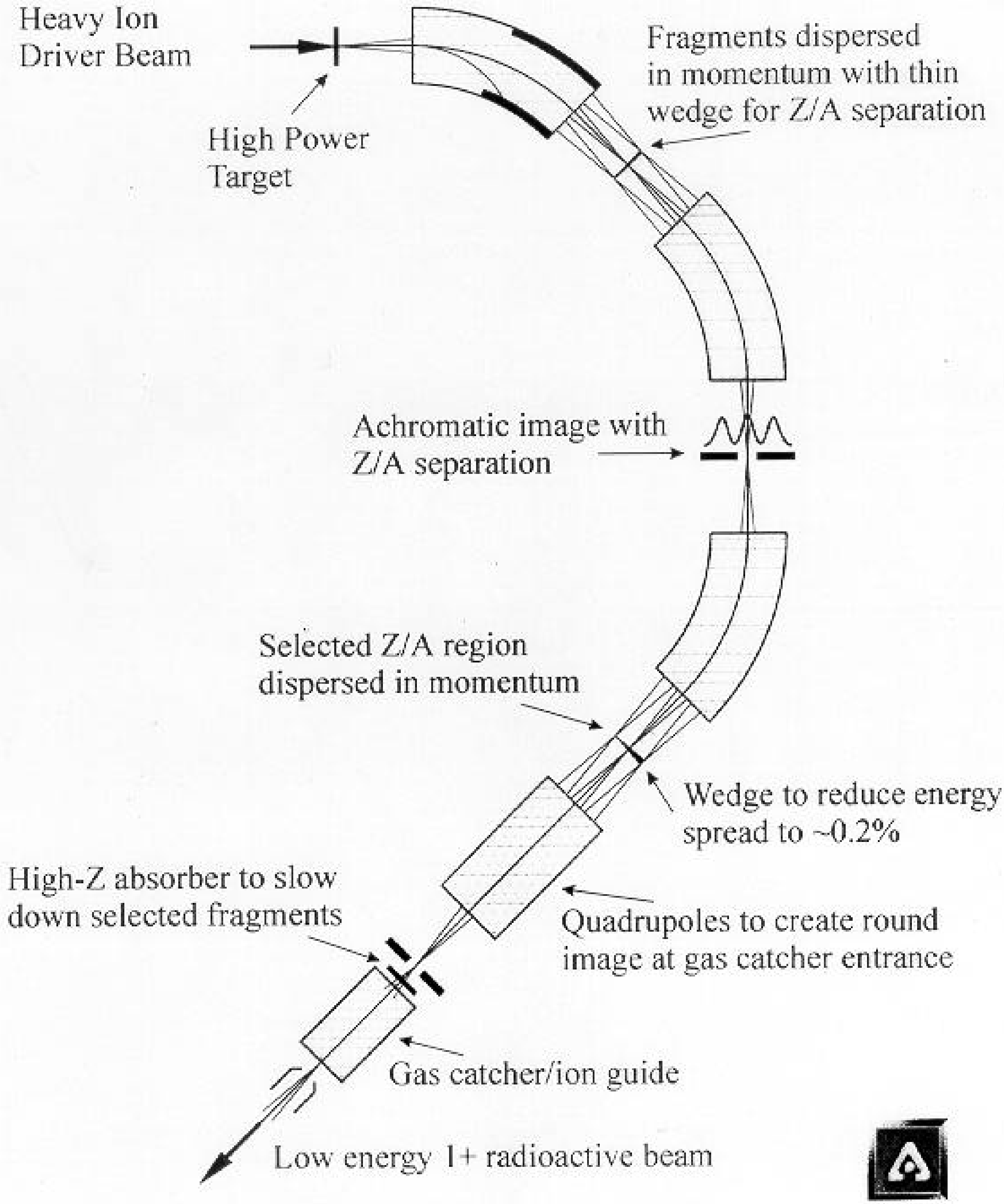


Projectile Fragmentation Based ISOL Concept with a Multiple Beam (Heavy Ion) Driver

- Fast Extraction Times (~msec)
- Chemical independence
- Isobar separation

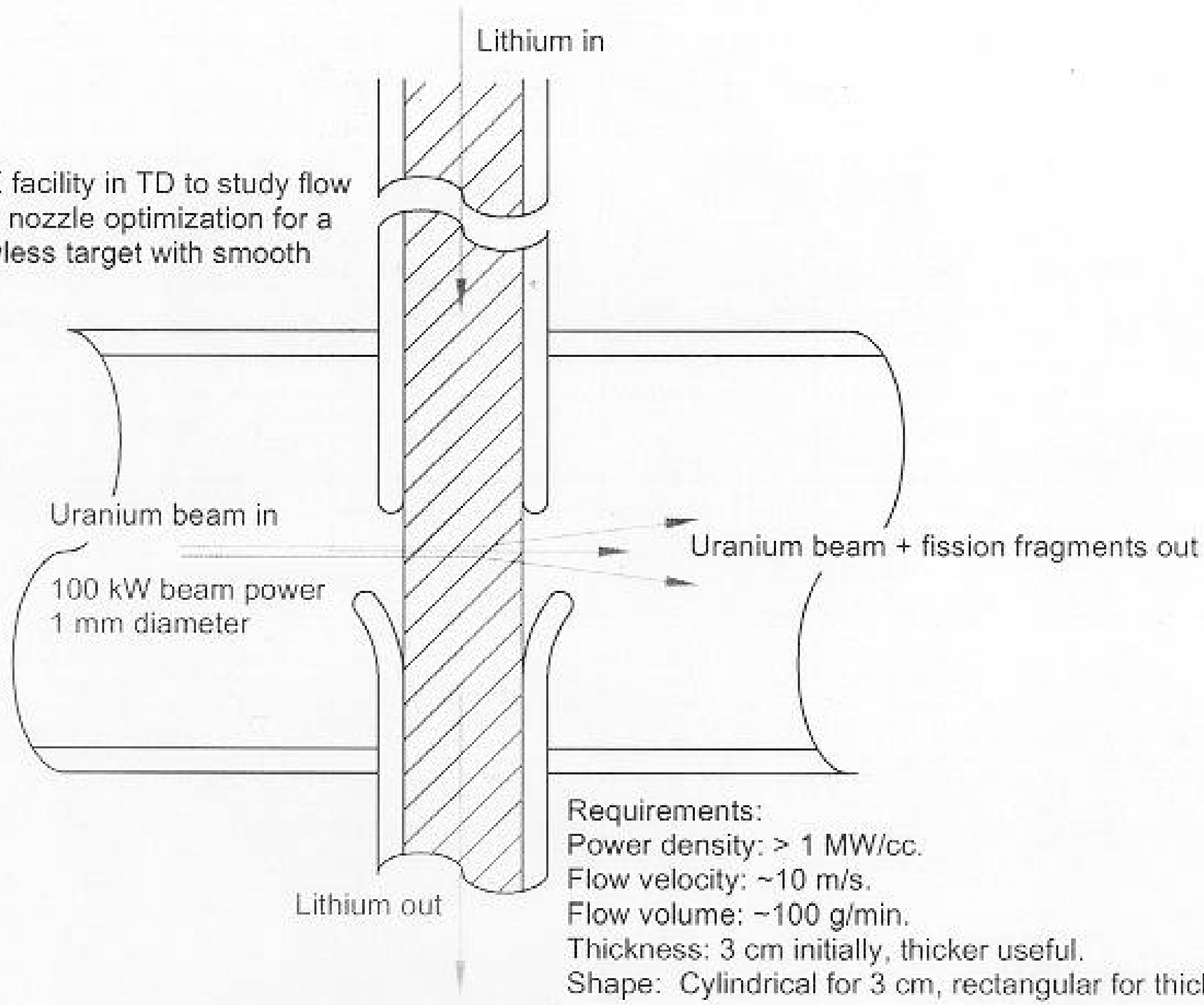


Schematic Layout of Fragment Separator and Gas Catcher



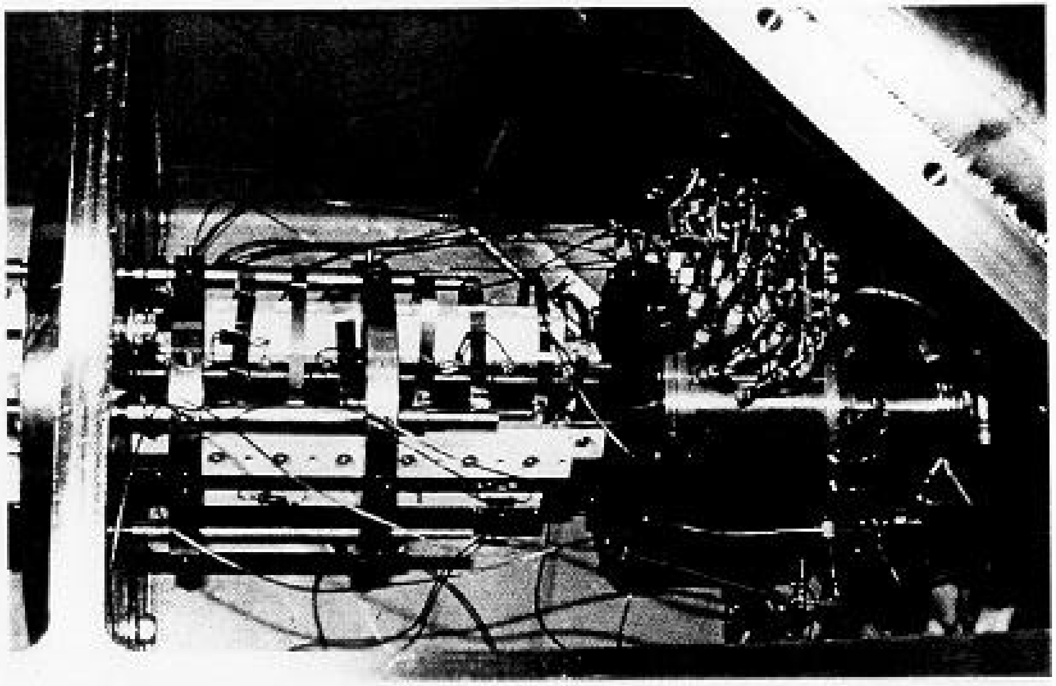
Concept for 3 cm thick windowless flowing liquid lithium target

Issues:
Use the ALEX facility in TD to study flow dynamics and nozzle optimization for a stable windowless target with smooth surfaces.



Requirements:
Power density: > 1 MW/cc.
Flow velocity: ~10 m/s.
Flow volume: ~100 g/min.
Thickness: 3 cm initially, thicker useful.
Shape: Cylindrical for 3 cm, rectangular for thicker.

Fast-Gas Catcher



- Ions are stopped in helium gas, where they remain ionized with high efficiency, the ions are extracted with electromagnetic techniques. The result: an entirely new paradigm for producing rare isotopes. Working prototype in use at ANL.
- ANL-GSI-MSU-RIKEN Collaboration to test at full energy.

Gas Catcher Performance